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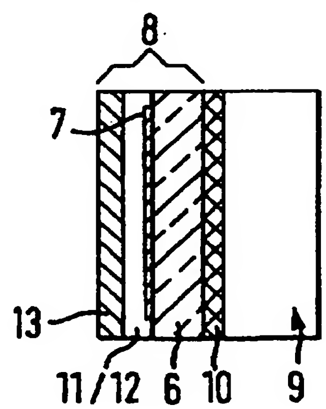
(54) **Efficient backlighting for lcds**

(57) A display comprising a light modulator defining between a transmissive rear support element and a transmissive front support element a plurality of selectively addressable regions which can be switched between at least an opaque state and a transmissive state, and a light emitting device (8) arranged adjacent the light modulator (9) and fixed to the same comprising a substrate (6) on which is formed a continuous first electrode layer (7), a continuous light emitting layer (11) and a second electrode layer (13) which extends continuously over the light emitting layer (11) to encapsulate an active area of the light emitting device (8).



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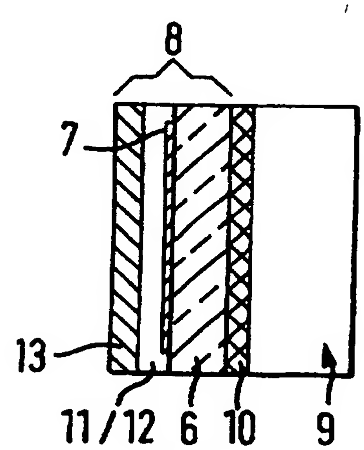
(57) Abstract

A display comprising a light modulator defining between a transmissive rear support element and a transmissive front support element a plurality of selectively addressable regions which can be switched between at least an opaque state and a transmissive state, and a light emitting device (8) arranged adjacent the light modulator (9) and fixed to the same comprising a substrate (6) on which is formed a continuous first electrode layer (7), a continuous light emitting layer (11) and a second electrode layer (13) which extends continuously over the light emitting layer (11) to encapsulate an active area of the light emitting device (8).



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EFFICIENT BACKLIGHTING FOR LCDs

Technical Field

The present invention relates to the use of organic light emitting devices (LEDs) as backlights for liquid crystal displays (LCDs).

Background Art

Liquid crystal materials are very widely used in display cells, working as a light valve. Their principle of operation is well known. LCDs are purely passive devices, and can only be used to switch, i.e., transmit, block or partially transmit, light that comes from another source. The source of light that is intended to be used will depend on the application of the display, but the LCD will broadly be one of: reflective - where incident light is reflected by a mirror situated behind a rear polariser on the LCD; transflective - where a partially opaque/partially reflective coating is applied to the rear polariser which will reflect incident light when conditions are bright enough, but will also allow light provided by a backlight mounted behind the LCD to pass through the coating and so allow the LCD to be read; or transmissive - where all the

light switched by the LCD is supplied from a backlight.

Existing methods for providing a backlight for transflective LCDs require separate elements to perform the reflection and light generation functions. For example, in a transflective LCD, a semi-opaque film is applied to the back of the rear polariser on the LCD, and then a light source is additionally coupled to the semi-opaque film. This light source could for example involve the use of inorganic electroluminescence (IEL) or discrete LEDs combined with waveguides. LEDs as backlights are generally preferred because they are driven from a dc power source at voltages which are normally available within the product in which the LCD is incorporated. However, they have the disadvantage of requiring a bulky waveguide, which can be difficult to assemble to the display, and, being point sources of light, they can give a very non-uniform appearance to the LCD, which is undesirable. IEL backlights could present a more attractive option because they supply a very uniform light output which lends a good appearance to the LCD and they have a very good form factor, being both thin and lightweight. IEL has the disadvantage, however, of being required to be driven by a relatively high voltage ac source, e.g., 90V at 400Hz, which is not normally available and requires an inverter to be built into the product. This is expensive and would require space within the product,

eliminating the form factor advantage of the IEL backlight. The inverter can also generate electromagnetic radiation which can cause problems depending on the application. Moreover, the electroluminescent layer in the IEL device is relatively thick, e.g., of the order of 100μm.

Both of these techniques also have the disadvantage of being inefficient, as only a percentage of the light generated is actually passed through the LCD, due to losses through the semi-opaque film.

It is an aim of the present invention to provide a liquid crystal display incorporating an improved backlight.

Disclosure of the Invention

According to an aspect of the present invention there is provided a display comprising a light modulator defining between a transmissive rear support element and a transmissive front support element a plurality of selectively addressable regions which can be switched between at least an opaque state and a transmissive state, and a light emitting device arranged adjacent the light modulator and fixed to the same comprising a substrate on which is formed a continuous first electrode layer, a continuous light emitting layer and a second electrode layer

which extends continuously over the light emitting layer to encapsulate an active area of the light emitting device.

A transflective LCD can easily be made in this fashion, where the second electrode layer is reflective.

In one embodiment, the rear support element carries an optical polariser to which is secured the substrate of the light emitting device.

In an alternative embodiment, the substrate of the light emitting device itself can constitute the optical polariser for the light modulator.

The light emitting device may be fixed to the light modulator by laminating or bonding, or by securing with edge clips.

In one embodiment, the light modulator has an array of selectively addressable regions (pixels) organised in rows and columns.

In order to operate the display, addressing circuitry can be provided comprising column drive circuitry for applying, for each selected row, data voltages on selected ones of column electrodes, and row addressing circuitry for

sequentially addressing rows of pixels.

In a preferred embodiment, the light emitting layer comprises a semiconductive conjugated polymer such as polyphenylenevinylene (PPV) or its derivatives. Such semiconductive conjugated polymers are described for example in US-5247190, the contents of which are herein incorporated by reference. Alternatively, the light emitting layer can take the form of an organic molecular film which, when excited, emits light. Suitable organic molecular films are disclosed in C.W. Tang, S.A. Van Slyke and C.H. Chen, Journal of Applied Physics, 65, 3610 (1989).

As some of the materials used in such organic LEDs can be very susceptible to moisture and oxygen, good encapsulation is important for longevity of the devices.

Preferably, therefore, the second electrode layer is formed of a material which is a barrier to water and oxygen.

Where an organic light emitting layer is used, it can be very thin, e.g., of the order of 100nm. Thus, there is very little absorption of light. This contrasts with the thicker layers in the IEL devices which tend to scatter light.

The light emitting device can be formed on a flexible substrate, since where the rear support element of the light modulator is rigid, the flexible substrate of the light emitting device is thus supported.

Moreover, this effectively encapsulates the substrate side of the device and where the second electrode layer acts as a barrier to water and oxygen, the other side of the device is effectively encapsulated, providing a completely encapsulated device at low cost.

When the light emitting layer is a semiconductive conjugated polymer, it emits light when electrically excited. Electrical excitation takes place by application of a voltage between the electrode layers on either side of the light emitting layer, which causes charge carriers of opposite types to be injected into the light emitting layer. These charge carriers recombine and decay radiatively to cause light to be emitted from the light emitting layer.

In addition to the light emitting layer, an additional polymer layer can be included to act as a charge transport layer or an additional light emitting layer.

The first electrode layer can constitute an anode of indium tin oxide, while the second electrode layer can

constitute a cathode of aluminium. Alternatively, the second electrode layer could be magnesium, calcium or an alloy of these materials with a more stable but higher work function metal. Preferably, the second electrode layer is formed of a material having a work function of less than 4.2eV.

According to another aspect of the present invention there is provided a method of making a display comprising: forming a first electrode layer on a substrate; forming a layer of a light-emissive material onto the first electrode layer; forming a second electrode layer of a material which is a barrier to water and oxygen over the light-emissive material to encapsulate an active area of the light-emissive material; securing the substrate to a light modulator defining between a transmissive rear support element and a transmissive front support element a plurality of selectively addressable regions switchable between at least an opaque state and a transmissive state.

Within the scope of the present invention, various embodiments provide the following methods of making displays.

A method for making a transflective LCD with an efficient backlight by laminating or bonding an organic LED

to the surface of the rear polariser on an LCD, where the organic LED is fabricated on a substrate which is essentially impermeable to oxygen and water.

A method for making a transflective LCD with an efficient backlight by laminating or bonding an organic LED to the rear surface of an LCD, where the organic LED is fabricated on a flexible substrate and the substrate of the LCD provides secondary encapsulation for the organic LED.

A method for making a transflective LCD with an efficient backlight by laminating an organic LED to the surface of the rear polariser on an LCD, where the organic LED is fabricated on a flexible substrate and the LED is encapsulated by laminating a water and oxygen barrier layer over the same.

According to an embodiment of the present invention, there is provided a transflective LCD structure with an efficient backlight where a single substrate is used as a carrier for the rear polariser for a transmissive LCD and as a substrate for an organic LED.

<u>Brief Description of the Drawings</u>

For a better understanding of the present invention and

to show how the same may be carried into effect, reference will now be made by way of example to the following drawings, in which:

Figure 1 is a diagrammatic side view of a known LCD;

Figure 2 is a section through a light emitting structure;

Figure 3 is a sketch of a structure according to one embodiment of the present invention;

Figure 4 is a sketch of a structure according to a second embodiment of the present invention;

Figure 5 is a sketch of a structure according to a third embodiment of the present invention; and

Figure 6 shows the structure of Figure 3 with associated control circuitry.

Best Mode for Carrying out the Invention

Figure 1 illustrates a known liquid crystal display structure. A layer 4 of liquid crystal material is sandwiched between two glass substrates 1a, 1b. On the first glass substrate 1a are defined row conducting electrodes 2 in contact with the liquid crystal layer 4. On the second glass substrate 1b are defined column conducting electrodes 3 in contact with the liquid crystal layer 4. To allow transmission of light through the LCD, these electrodes are typically transparent. The row electrodes 2

extend horizontally and the column electrodes 3 extend vertically. Where the row and column electrodes 2, 3 overlap, pixels are defined in the liquid crystal layer 4. These pixels constitute addressable regions which can be controlled by voltages applied to the row and column electrodes 2, 3 so as to be transmissive (i.e., to transmit light) or to be opaque (i.e., to block light). The state of the pixels depends on the magnitude of the electric fields applied between the row and column electrodes 2, 3 at the point of overlap defining the respective pixels.

A polariser 10 in the form of a coated plastic film is bonded to the rear surface of the first glass substrate 1a and covered by a semi-opaque film 5. Behind the polarizer 10, a backlight 18 is located, which is turned on to supply illumination when background conditions are not bright enough. When background conditions are bright enough, the semi-opaque film 5 acts as a reflector to reflect ambient light, and the backlight 18 is not then needed. A similar polariser is bonded to the front surface of the second glass substrate 1b but is not shown.

The structure of Figure 1 however suffers from the disadvantages already discussed, where the backlight 18 is a plurality of discrete LEDs or uses IEL technology.

Figure 3 illustrates an LCD with an improved backlight in the form of an organic LED. The conventional backlight 18 and semi-opaque film 5 have been removed from the structure of Figure 1, so that the LCD has become a transmissive LCD, and replaced with an organic LED as a backlight 8. The structure of the organic LED is shown in Figure 2. The LED 8 is made on a glass substrate 6, which carries a transparent indium tin oxide (ITO) layer 7 with a resistivity of 30 ohms/square. On top of ITO layer 7 is a 500 Angstrom layer of polyphenylenevinylene (PPV) 11 which has been spin coated as a precursor and thermally converted to form the polymer. On top of PPV layer 11 a 500 Angstrom layer 12 of Alq_3 is sublimed. An aluminium electrode layer 13 is then evaporated on top of the Alq_3 layer 12. The ITO layer 7 has been etched away from an area 7a 1mm wide around the edge of the substrate 6 prior to the deposition of subsequent layers. A physical mask was used to prevent deposition of the Alq_3 layer 12 outside this area. The aluminium electrode layer 13 is subsequently deposited across the whole substrate area and so encapsulates the whole active electronic area. As described in our earlier US-5247190, when an electric field is applied between the electrode layers 7, 13 which exceeds the charge injection threshold, light is emitted from the PPV layer 11. The light from the organic LED 8 is used to backlight the transmissive LCD cell 9 by placing the front surface of the

substrate 6 in intimate contact with the rear polariser 10 on the LCD cell 9 - see Figure 3.

An experiment to compare the power consumption with the prior art was set up as follows. The standard transflective LCD and backlight assembly of Figure 1 were run at the prescribed operating conditions and the light output at the front of the LCD was measured at 10cd/m^2. The power consumed by the backlight 18 at this output was 135mW.

The LCD and organic LED backlight of Figure 3 were then set up and run at the same level of brightness achieved by the previous experiment. The power consumed was 50mW which is 37% of the power required for the conventional backlight 18, and at the same time a more uniform appearance was provided. The metallic nature of the rear electrode 13 of the organic LED 8 means that incident light is reflected back through the LCD, combining the functions of reflector and backlight into one component.

One of the advantages of organic LEDs is that the light emitting layer or layers can be deposited in a continual process such as blade coating or reel to reel coating, and then the top electrode can also be deposited by a continual process such as sputtering. This enables the fabrication of large areas of organic LED and reduces the manufacturing

cost. In operation, however, the materials used as the light emitting layer(s) are sensitive to water and oxygen, whose presence can speed up the degradation of the light output of the device. A requirement for good continuous operation of the backlights is therefore good encapsulation of the active layers against this ingress.

One of the most effective barriers is a pinhole free metal or metal oxide film, such as aluminium. The structure of Figure 3 has a continuous aluminium film as the top electrode 13, which in addition to providing a reflective rear layer, also has the advantage of providing an efficient barrier to the ingress of water and oxygen into the device.

For devices fabricated in a continuous process as described, it is necessary to have a substrate which is transparent, carries a transparent electrode and is flexible enough to allow it to pass through the path of the coating equipment. Typical substrates are PET coated with an ITO electrode, but many other thermoplastics and electrode materials can also be used, such as tin oxide, polycarbonates and polyethylene napthalate. The thermoplastic substrates used do not typically provide a suitable barrier to water and oxygen for the purposes of organic LED operation. Ideally, the ITO layer on top of the thermoplastic would provide an effective barrier, in the

same way as the top electrode. However, ITO is fairly brittle and is deposited on top of a soft material and this combination is repeatedly bent during processing. This leads to cracking of the ITO layer which reduces the integrity of the ITO layer as a barrier layer.

A major drawback of organic LEDs fabricated on flexible substrates has therefore been the lack of an effective oxygen and water barrier for the substrate side of the device, which has led to poor device lifetimes. Glass can provide a suitable encapsulation to give extended lifetimes, but does not have the necessary flexibility for in-line processing.

This problem is overcome with the structure of Figure 4, in which the organic LED 8' is mounted and secured in intimate contact with the polariser 10 which covers the glass substrate 1a. Figure 4 shows an organic LED backlight which has substantially the same structure as the device shown in Figure 3 except that the substrate 6' is made from flexible PET rather than glass.

By using a suitable mounting method, such as bonding with cyano-acrylate or epoxy based adhesives, the flexible substrate 6' of the organic LED is attached to the polariser 10 on the transmissive LCD cell 9. The LED 8' is bonded to

the rear polariser 10 on the LCD cell 9 using a cyano-acrylate adhesive 14.

This effectively forms an encapsulation system for the substrate side of the organic LED, reducing the ingress of oxygen and water to the point where the organic LED on a flexible substrate has a sufficiently extended lifetime to be a practical commercial product. This means that a low cost manufacturing route can be used and still produce backlights that have commercially acceptable lifetimes because of the additional level of encapsulation provided by the substrate of the LCD that is being illuminated.

Additionally, because there is no need for the semi-opaque transflective layer 5, the power consumed by the backlight to give the same illumination is less, making the device more efficient than conventional backlighting systems.

Figure 5 illustrates another embodiment of the present invention. By using the rear polariser as the substrate for the organic LED, it is possible to further integrate the organic LED and the LCD cell.

Figure 5 shows the structure of an organic LED, essentially the same as in Figure 1, with the exception that

the rear polariser 10' for the LCD cell 9 is used as the substrate. The layer structure is made up as in the embodiment of Figure 3. An ITO layer 7 is sputtered on top of the polariser 10'. On top of the ITO layer 7 is a 500 Angstrom layer of polyphenylenevinylene (PPV) 11 which has been spin coated as a precursor and thermally converted to form the polymer. On top of PPV layer 11 a 500 Angstrom layer of Alq_3 12 is sublimed. An aluminium electrode layer 13 is then evaporated on top of the Alq_3 layer 12. The ITO layer 7 has been etched away from an area 1mm wide around the edge of the polariser 10' prior to the deposition of subsequent layers. A physical mask was used to prevent deposition of Alq_3 outside of this area. The aluminium electrode layer 13 is subsequently deposited across the whole substrate area and so encapsulates the whole active electronic area. When an electric field is applied across the electrode layers 7, 13 which exceeds the charge injection threshold, light is emitted from the PPV layer 11.

This composite polariser/backlight is then bonded or laminated to an LCD cell 9, which has another, conventional polariser (not shown) attached to its front surface. The intimate contact with which the polariser 10' is attached to the glass of the LCD cell provides an encapsulation for the substrate of the organic LED and so allows the backlight to have a useful operational and storage lifetime while at the

same time having manufacturing cost advantages over conventional backlight assemblies.

Figure 6 illustrates the structure of Figure 3 together with its associated drive and addressing circuitry. The addressing circuitry comprises row addressing circuitry 17 for selectively addressing row electrodes 2 of the LCD and column drive circuitry 21 for selectively applying the required voltage to the column electrodes 3. An image data store 23 holds image data for controlling the column drive circuitry 21. A clock circuit 19 generates a clock signal which controls the timing of the signals output from the column drive circuitry 21. It also controls the timing of the row addressing circuitry 17.

Reference numeral 15 denotes a voltage supply for the electrode layers 7, 13 of the backlight. A switch 22 is provided for selectively turning the backlight on and off depending on the level of ambient light. For bright conditions, the backlight is not required. In that case, the rear electrode layer 13 will act as a reflector to form a transflective LCD structure. However, in dim light, the backlight can be turned on so that the LCD acts as a transmissive LCD.

Industrial Applicability

Organic electroluminescent elements, especially those incorporating EL polymers are well suited to application as backlights for LCDs in general and transflective LCDs in particular. The fact that they incorporate a metal electrode on top of thin organic layers means that when the organic LED is not energised, it is reflective. Thus, if an organic LED is used in place of the reflective film or semi-opaque film at the back of an LCD it will take the place of the reflector in conditions of high ambient light when the LED is not energised and will act as a backlight when ambient light levels are low. This reduces the complexity and total size of the complete assembly, and increases the efficiency of the total system, because all of the light generated by the backlight is coupled to the LCD and there is no semi-opaque film to pass through. This means that the backlight can be operated at low output and still give the same brightness at the front of the LCD, which means that battery life of the product into which the device is incorporated can be extended.

There has been described a way of combining reflection and light generation aspects of transflective LCD backlighting onto one substrate, avoiding the inefficiency and assembly steps associated with traditional means and in

the process extending the life of the organic LED by providing efficient encapsulation.

<u>CLAIMS</u>:

1. A display comprising a light modulator defining between a transmissive rear support element and a transmissive front support element a plurality of selectively addressable regions which can be switched between at least an opaque state and a transmissive state, and a light emitting device arranged adjacent the light modulator and fixed to the same comprising a substrate on which is formed a continuous first electrode layer, a continuous light emitting layer and a second electrode layer which extends continuously over the light emitting layer to encapsulate an active area of the light emitting device.

2. A display according to claim 1, wherein the second electrode layer is reflective.

3. A display according to claim 1 or 2, wherein the second electrode layer is formed of a material which is a barrier to water and oxygen.

4. A display according to any of claims 1 to 3, wherein the substrate of the light emitting device is flexible and is supported by the rear support element of the light modulator, which is rigid.

5. A display according to any of claims 1 to 4, wherein the rear support element carries an optical polariser to which is secured the substrate of the light emitting device.

6. A display according to any of claims 1 to 4, wherein the substrate of the light emitting device constitutes an optical polariser for the light modulator.

7. A display according to any of claims 1 to 6, wherein the light emitting device is fixed to the light modulator by laminating or bonding.

8. A display according to any of claims 1 to 7, wherein the light modulator comprises a layer of liquid crystal material disposed between a first set of row electrodes and a second set of column electrodes, said regions being defined where the row electrodes and column electrodes overlap.

9. A display according to claim 8, including addressing circuitry comprising column drive circuitry for applying, for each selected row, data voltages on selected ones of said column electrodes, and row addressing circuitry for sequentially addressing said rows.

10. A display according to claim 9, wherein said row

addressing circuitry and said column drive circuitry are controlled by a common clock circuit to ensure synchronisation thereof.

11. A display according to any of claims 1 to 10, wherein the light emitting layer comprises a semiconductive conjugated polymer.

12. A display according to claim 11, wherein the semiconductive conjugated polymer is polyphenylenevinylene (PPV) or a derivative thereof.

13. A display according to any of claims 1 to 10, wherein the light emitting layer comprises an organic molecular film.

14. A display according to any of claims 1 to 13, wherein the first electrode layer constitutes an anode of indium tin oxide and the second electrode layer constitutes a cathode of aluminium.

15. A display according to any of claims 1 to 14, wherein the light emitting device includes one or more further layers for enhancing operation of the device.

16. A display according to claim 15, wherein one of said

further layers is Alq_3 and acts as an optical brightener.

17. A method of making a display comprising the steps of:

forming a first electrode layer on a substrate;

forming a layer of a light-emissive material onto the first electrode layer;

forming a second electrode layer of a material which is a barrier to water and oxygen over the light-emissive material to encapsulate an active area of the light-emissive material;

securing the substrate to a light modulator defining between a transmissive rear support element and a transmissive front support element a plurality of selectively addressable regions switchable between at least an opaque state and a transmissive state.

18. A method according to claim 17, wherein the rear support element carries an optical polariser to which is secured the substrate.

19. A method according to claim 17, wherein the substrate constitutes an optical polariser for the light modulator.

20. A method according to any of claims 17 to 19, wherein the substrate is flexible and is supported by the rear support element of the light modulator, which is rigid.

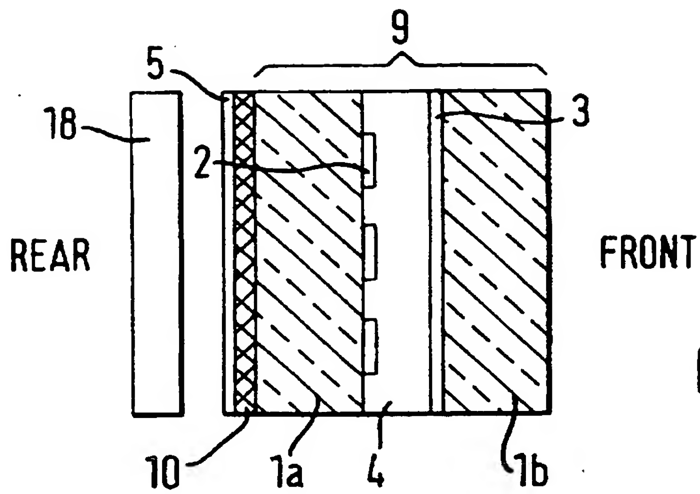

FIG. 1

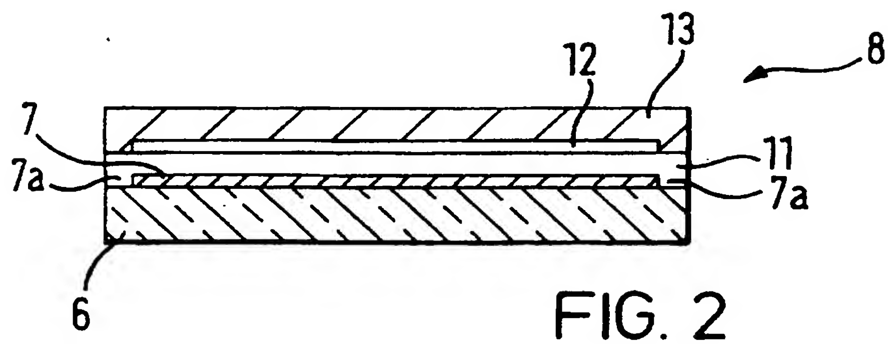

FIG. 2

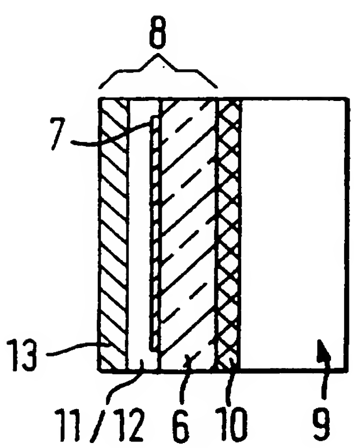

FIG. 3

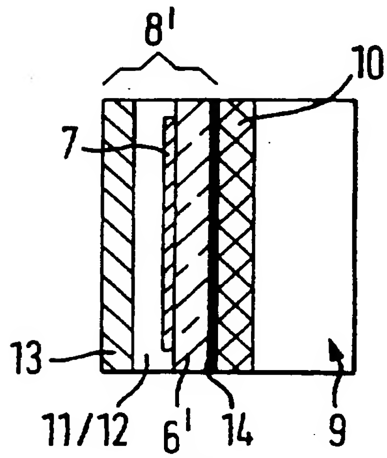

FIG. 4

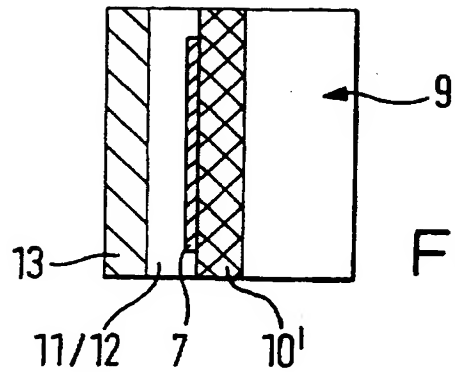
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FIG. 5

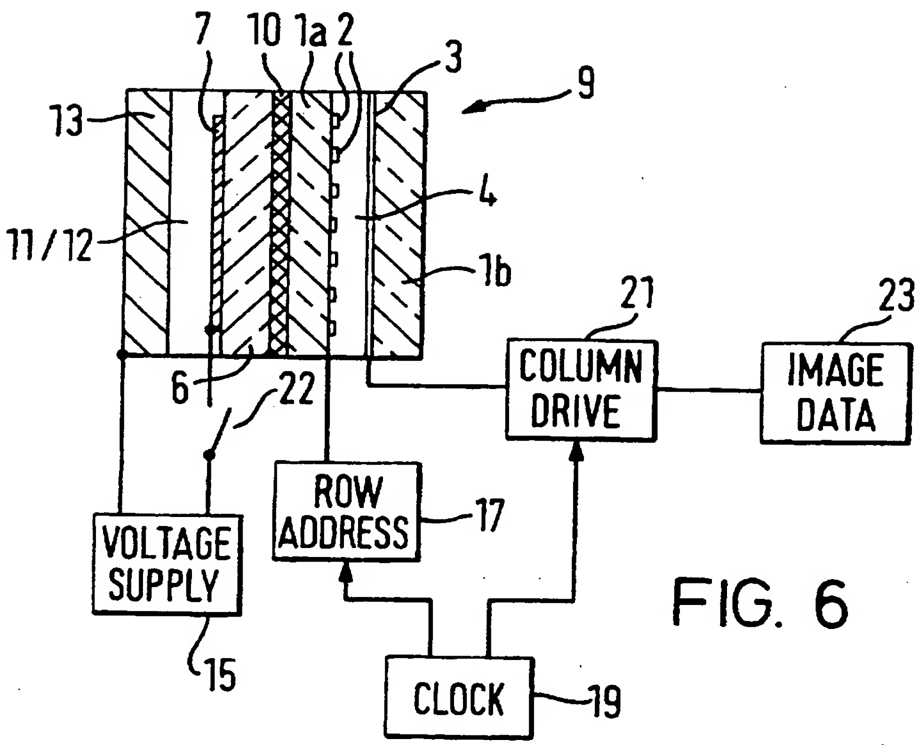
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IMAGE DATA
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ROW ADDRESS
17
VOLTAGE SUPPLY
15
CLOCK
19

FIG. 6

INTERNATIONAL SEARCH REPORT

Inter nal Application No
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A. CLASSIFICATION OF SUBJECT MATTER
IPC 6 G02F1/1335

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED
Minimum documentation searched (classification system followed byclassification symbols)
IPC 6 G02F

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	PATENT ABSTRACTS OF JAPAN vol. 8, no. 137 (P-282) '1574! , 26 June 1984 & JP 59 037530 A (HITACHI), 1 March 1984,	1,2,5, 7-10,17, 18
Y	see abstract	3,4, 11-15,20
Y	US 4 775 820 A (K.EGUCHI ET AL) 4 October 1988 see column 23; figure 1	3,4,13, 14,20
Y	EP 0 701 290 A (MOTOROLA) 13 March 1996 see the whole document	11,13,15

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[X] Further documents are listed in the continuation of box C.

[X] Patent family members are listed in annex.

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"A" document defining the general state of the art which is not considered to be of particular relevance
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1

Date of the actual completion of the international search	Date of mailing of the international search report
2 July 1997	14/07/1997

Name and mailing address of the ISA	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Tx. 31 651 epo nl, Fax: (+31-70) 340-3016	Malic, K

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C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	NATURE, vol. 370, no. 6488, 4 August 1994, pages 354-357, XP000466647 V.L.COLVIN ET AL.: "LIGHT-EMITTING DIODES MADE FROM CADMIUM SELENIDE NANOCRYSTALS AND A SEMICONDUCTING POLYMER" see abstract ---	12,13
Y	PATENT ABSTRACTS OF JAPAN vol. 8, no. 79 (P-267) '1516! , 11 April 1984 & JP 58 221828 A (SHARP), 23 December 1983, see abstract ---	3,15
X	DE 30 37 224 A (PHILIPS PATENTVERWALTUNG) 29 April 1982 see page 9 - page 10; figures 1-3 -----	1,2,5-7, 17-19

INTERNATIONAL SEARCH REPORT

Information on patent family members

International Application No
PCT/GB 97/00939

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
US 4775820 A	04-10-88	JP 4046311 B	29-07-92
		JP 61037858 A	22-02-86
		JP 61037859 A	22-02-86
		JP 61037860 A	22-02-86
		JP 61037861 A	22-02-86
		JP 61037862 A	22-02-86
		JP 61037863 A	22-02-86
		JP 61037864 A	22-02-86
EP 701290 A	13-03-96	JP 8088402 A	02-04-96
DE 3037224 A	29-04-82	NONE	